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means of a systematic view of natural processes. The question what is time, or what are equal times, is a matter of definition. Equal times are those in which identical events take place. Time is concerned only with events, and we know nothing of empty time. There is no criterion of identical events independent of time, and we must be content with assuming that two events are identical when it is more reasonable to assume that than the contrary. The paper closes with a criticism of the recent mathematico-physical definitions of equal times.

#### TOUCH, PAIN, INTERNAL SENSATIONS.

GOLDSCHIEDER. *Ueber die Summation von Hautreizen*, Dubois-Reymond's Archiv 1891, 164.

Lightly stimulate the skin with the point of a pin, or even a somewhat blunter instrument. A pricking sensation arises, dies away, and is succeeded by a secondary, or after-sensation, which also has the prickly feeling, but lacks the touch-tone which marked the primary one. It seems very much more as if it came from within. If the stimulus be stronger, but at the same time not quite strong enough to make the primary sensation painful, the secondary sensation will be felt as painful. But if the strength of the stimulus be still further increased so as to give the painful tone to the primary sensation, then the secondary is feebler than the primary, and does not flash out as clearly, since the interval between the two is partly filled by the persistence of the primary sensation. Goldscheider found that a single electric shock in no case gave rise to this secondary sensation. In order that it should arise it was necessary to make a number of such stimuli, one after another, on the same spot. This gave a clue to the explanation of the above phenomenon, and also suggested lines of experiment. He and Herr Gud sought to determine under what conditions a series of stimuli is competent to produce the secondary sensation,—how long the series must last, what the interval should be between the shocks, and what the intensity of the current. A series of four gives a clear secondary sensation, but only with certain intervals between the stimuli. With an interval of from 0.03 to 0.06 second, the sensation is most clear. As the interval is made smaller than the former number, or larger than the latter, the secondary sensation becomes less and less clear, finally disappearing altogether. The like is true if the number of stimuli in the series be increased. For each number a certain range of interval is found which gives the secondary sensation the maximum of distinctness. This interval varies, however, inversely with the number of the stimuli. The product of number by interval is found to be (nearly) constant.

In each case a certain intensity is found best fitted to give the secondary sensation. Increasing or diminishing the intensity beyond this point enfeebles the effect. The time elapsing from the end of the series to the rise of the secondary sensation was measured and found to be (on the hand) about  $\frac{1}{10}$  second. Increasing the duration of the series by increasing either the number of stimuli or the interval between them has no appreciable effect on this time, until the point is reached when the number of stimuli given is just the number necessary (with each particular interval) to bring out clearly the secondary sensation. If we increase the number beyond this point, the secondary sensation comes out independently of the duration of the series, but with its same time-interval. That is, increasing the duration of the series beyond this point, the interval between the end of the series and the rise of the secondary sensation is correspondingly shortened. When the series is made to last about  $\frac{1}{10}$  sec., the secondary sensation flows into the primary, or does not arise at all. Similar results are found with

mechanical stimulation. The reaction time is in effect the same, provided the intensity and duration are made as nearly as possible the same as with the electrical stimulation. Increasing the duration of the stimulation up to a certain point has no appreciable effect on the interval between the *end* of the stimulation and the rise of the secondary sensation. But when a certain point has been reached, then further increase in the duration has just the opposite effect. The interval from the *beginning* of the stimulation to the rise of the secondary sensation remains constant, while the interval measured from the *end* of the stimulation diminishes. The explanation, here, is the same as in the case of electrical stimulation; when the total stimulation has reached the intensity necessary to awaken the secondary sensation, a further increase of the stimulation has no effect on the time. The time required for the rise of the secondary sensation was found to be on the wrist shorter, and on the sole of the foot about half a second longer, than the time given above.

The secondary, or after-sensation, is a "summation-phenomenon." A mechanical stimulation, since it is competent to produce this secondary sensation, should never be regarded as a single stimulus, but always as a series of stimuli. Where this summation takes place it is impossible to say with certainty, but Goldscheider argues that it most probably takes place in the cellular elements scattered throughout the nerve tract. Each stimulus takes two paths; one goes directly to the centre of consciousness, the other is impeded on its way by the cellular elements and only succeeds in making its way on to the centre under certain conditions. The cells "store" the energy, and a series of stimuli is needed to make the stored energy amount to enough to express itself in action. When this does happen, however, these cells send also their message to the centre, but by a different path, which we may appropriately call the "summation-path." This summation-path, via the gray matter of the spinal cord, is the same as has been called the "pain-path." A single stimulus, if of exorbitant intensity, may be sufficient to break its way through this pain-path. When this is the case, we may have both the primary and the secondary sensations coming over the same path; in the original experiment, when we made the stimulus strong enough to give the pain tone to the primary sensation, we still had the secondary or summation-phenomenon, though, in this case, weaker than the primary.

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SERGI, *Su alcuni caratteri del senso tattile, Osservazioni sperimentali.* Rivista di filosofia scientifica, 1891 X. 590.

A series of electric forks of 50, 100, 250, 435, 500 and 1000 v. was employed, a rigid and obtuse point of brass being substituted for the long fine point used for writing on the drum. The point was applied to some point of the skin to test the limit of rapidity of the blows given by the point that could be perceived as separate. The fleshy part of the fingers could perceive the stimulus as a succession of blows up to 1000 per sec.; many other parts of the hand, the point of the tongue and the red parts of the lips perceived 500, the greater part of the skin perceived 435 per sec. as a succession, which increased in clearness down to 50 v. The question of the intensity of the excitation and the special sensitiveness of the organ stimulated are then taken up. The final results of the experiments can be summarized as follows: 1. The cutaneous surface is not everywhere equally sensitive to tactile stimuli of small intensity; the most sensitive parts are always the palmar extremities of the fingers. 2. Many parts of the skin, although giving a definite sensation of touch, do not give it in the same clear and distinct